



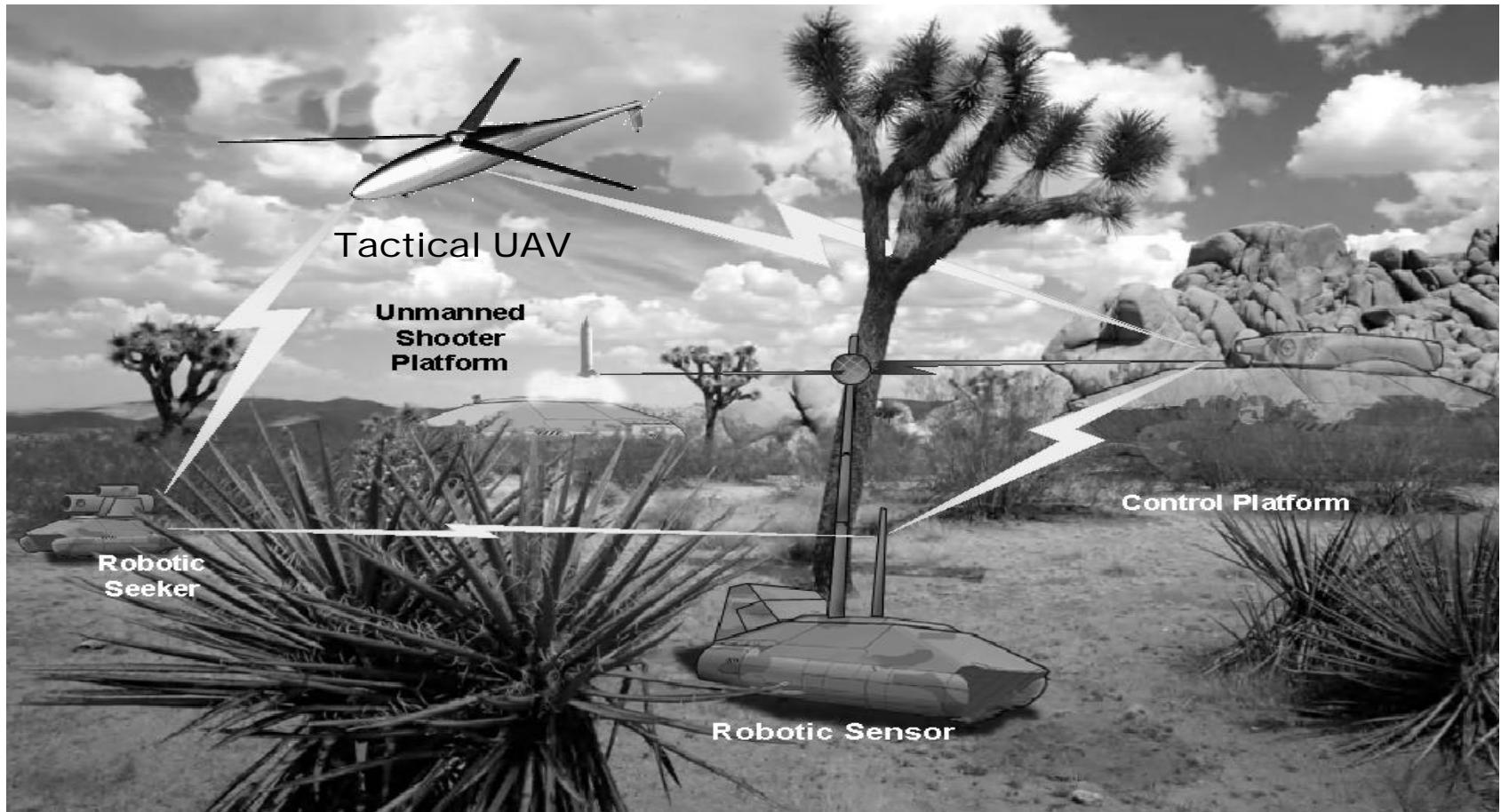
US Army TACOM-TARDEC Intelligent Mobility Program

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Robotics “Vision” for FCS

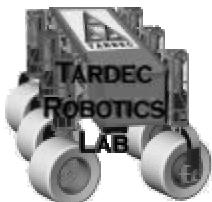


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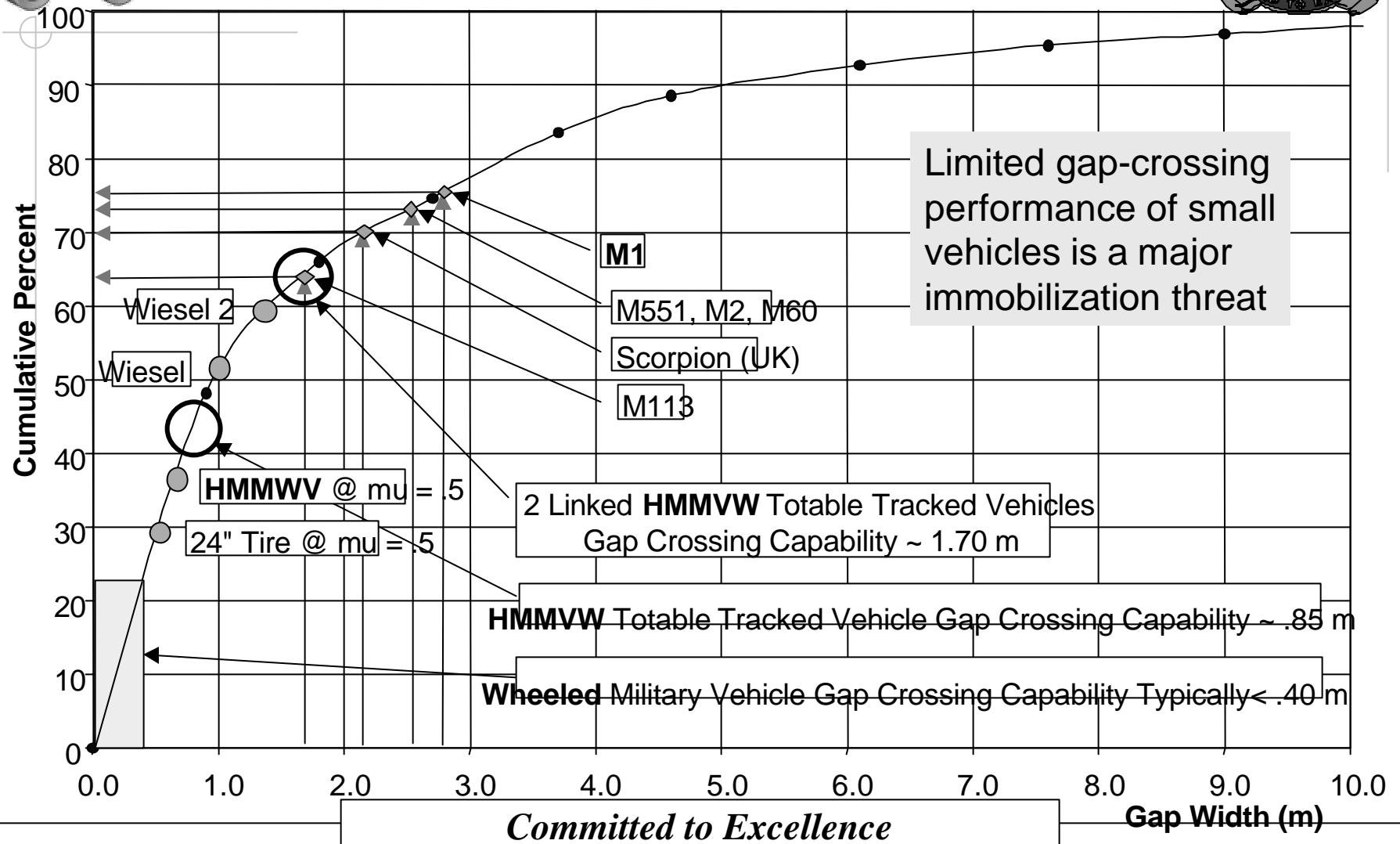
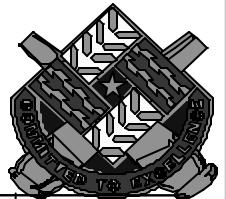


UGV Mobility Issues

Issues	Manned System	Unmanned System
Human Factors:	<ul style="list-style-type: none">• Absorbed Power• Rollover• Crash• Mine• Hit Risk <ul style="list-style-type: none">• 6 watts (driver seat)• No rollover / injury• No crash / injury• No mine encounter• Minimize	<ul style="list-style-type: none">• ± 30 g electronics• Self righting—operable• Crash tolerant—operable• Absorb blast—operable• Absorb hit—operable
Net Mobility Effect	<ul style="list-style-type: none">• Reduced cross country speed• Complex suspension• Limited route availability	<p>Higher cross country speed Simpler suspension</p> <ul style="list-style-type: none">• Higher payload fraction• Lower Cost• Better Trafficability• No personnel risk

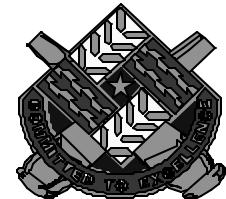


Gap Crossing Capability in Germany



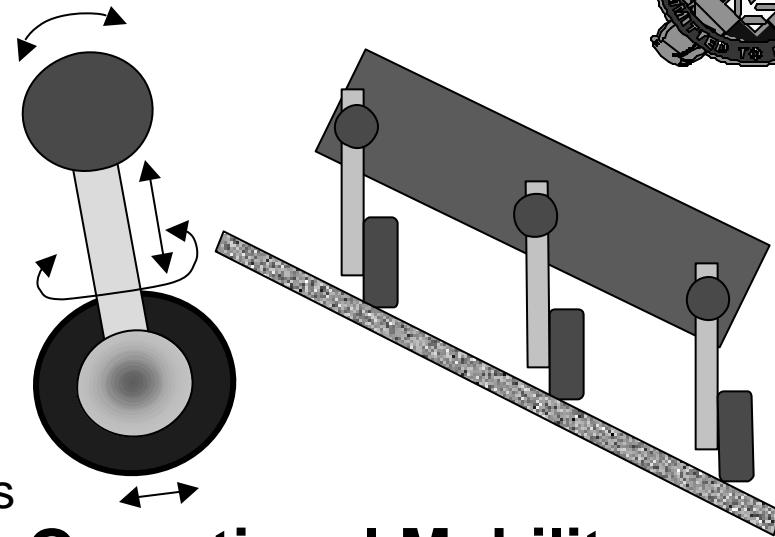
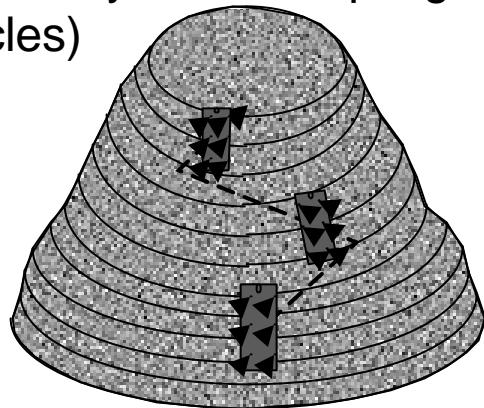


What Is Intelligent Mobility?



Inherent/Intrinsic Mobility

- Basic physical capability
- Ability to adjust the configuration and performance characteristics
- Governs the vehicle to execute commanded maneuvers and trajectories
- Advanced running gear, drive, control technologies and dynamic coupling (tandem vehicles)



Operational Mobility

- Applied mobility
- Governs and directs inherent mobility
- Selects the driving mode and route/velocity trajectory
- Advanced trajectory planning, navigation, learning and reactive behaviors

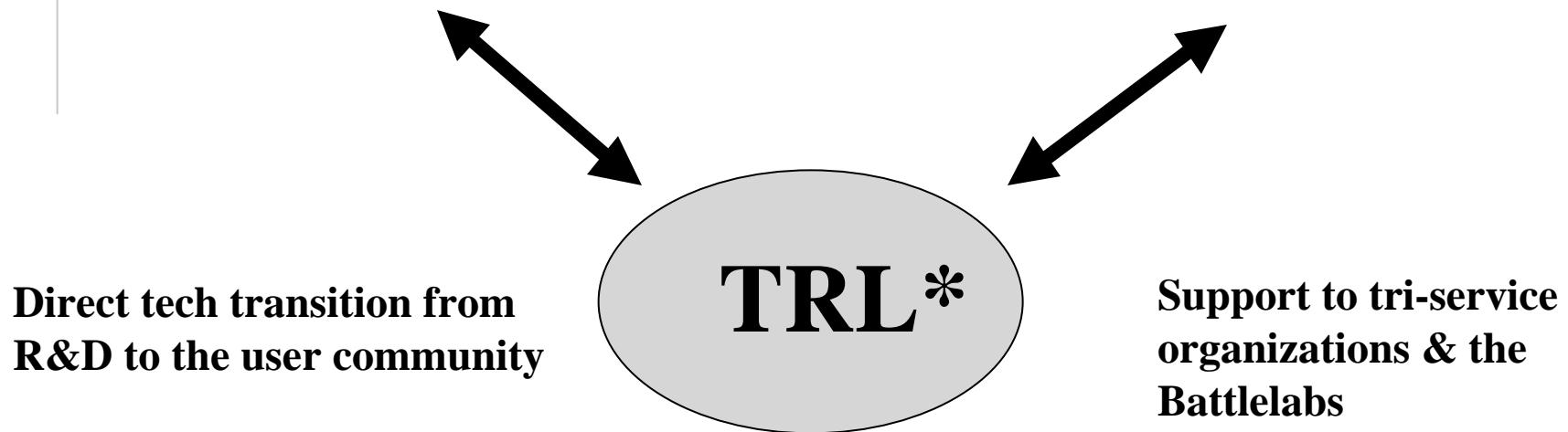
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Intelligent Mobility Program

**Ft. Benning
Ft. Knox
Ft. Leonard Wood**

**Tyndall AFRL
SPAWAR Navy
JPO Army**



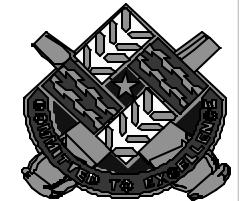
***TRL - TARDEC Robotics Laboratory**

Mix of research & customer funding

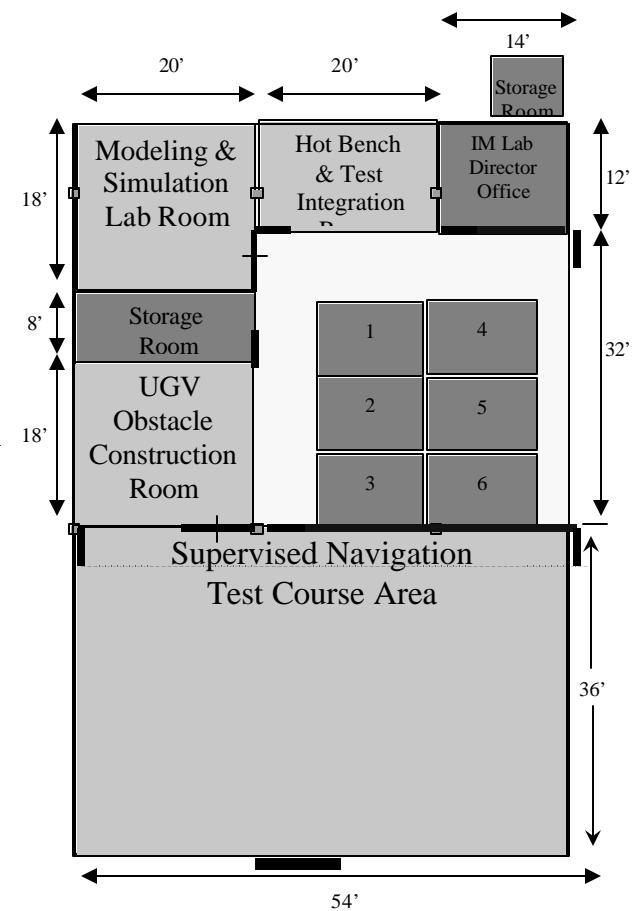
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TRL Facilities

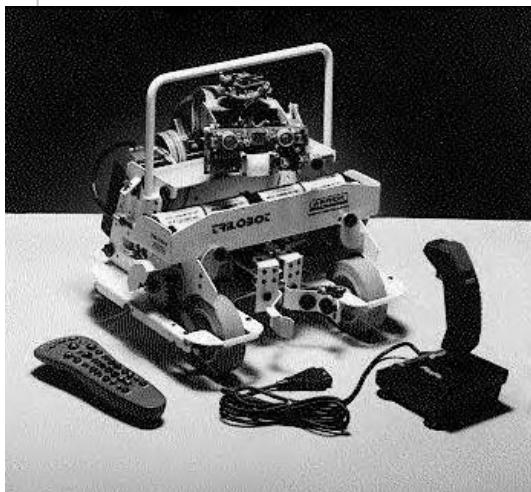
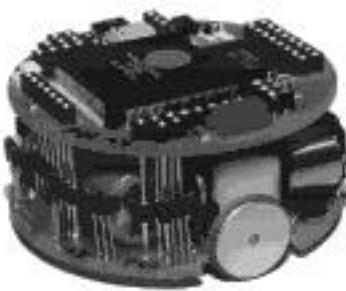


- ◆ Office Space for 10 personnel
- ◆ Behavioral Robotics lab
- ◆ Electronics integration room
- ◆ Modeling and simulation room
- ◆ Hardware room
- ◆ T&E bay for robots





Behavioral & Evolutionary Robotics Lab



- ◆ Creation of varying fidelity models of robots and sensors.
- ◆ Development of behavior-based navigation, mapping schemes.
- ◆ Transition to lab hardware and progressively larger, more complex robots (e.g predict performance).
- ◆ Development of Evolutionary Algorithms for tuning and improving robot performance.
- ◆ Evolve the controllers in simulation.
- ◆ Transition to robots to finish the job.

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Modeling & Simulation Lab



Perform mobility simulations
Perform model validations
Drive any hardware-in-the-loop bench testing
Assist NRMM upgrade?
Wargaming scenarios
Conduct “virtual” interactions with MOUT facilities via RAVENS



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RAVENS



RAVENS: Geographically distributed Soldier/Marine in-the-loop, Hardware in-the-loop, Software in-the-loop virtual & live analysis, test, & experiment architecture



- Assist Users in Requirements Development Efforts
- Assist the S&T community in Developing & Evaluating Technologies
- Assist in Risk Reduction Efforts
- Assist in Developmental and Operational Tests

Vision - Applying SBA/SMART principles to minimize cost, speed development, reduce risk, & ensure that Soldiers and Marines remain at the center of all system development efforts

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Terrain Classification Sub-System



<p><u>Objective & Approach</u></p> <ul style="list-style-type: none">- Generic, low-cost, light-weight, low power sensor package to sense vehicle dynamics and terrain properties- Machine learning algorithm to classify terrain type from sensor data	<p><u>FY 01 Milestones</u></p> <ul style="list-style-type: none">- Demonstrate prototype system- Evaluate on 6 terrain types
<p>3 DOF Inclinometer</p> <p>3 DOF Gyro</p> <p>Linear Encoder on Suspension</p> <p>Wheel Encoders</p> <p>Capacitance Sensor</p> <p>Ultra-Sonic Sensor (active)</p> <p>Linear Accelerometer</p> <p>Microphone</p> <p>Current & Voltage Sensors</p>	<p><u>Neural Net Classifier (single sensor)</u></p> <p>Grass</p> <p>Gravel</p> <p>Pavement</p>

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Negative Obstacle Detection System



Objective

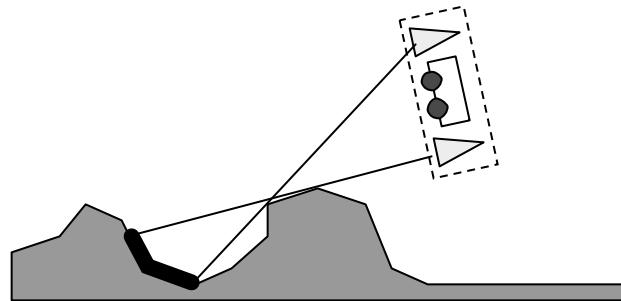
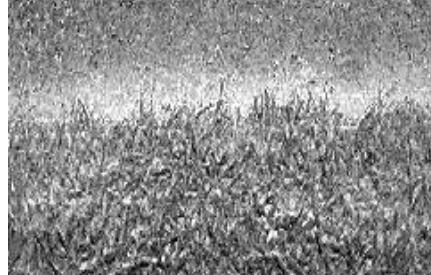
- Navigation vision system integrating multi-source projected light and trinocular stereo vision
- Downstream SWIR system in 1.8 to 2.0 micron CO2 absorbing “dark band”

FY 01 Milestones

- Demonstrate prototype system
- Evaluate as a function of obstacle
 - Size
 - Distance
 - Terrain cover

Shadows isolation locates negative features from over-lit and under-lit images.

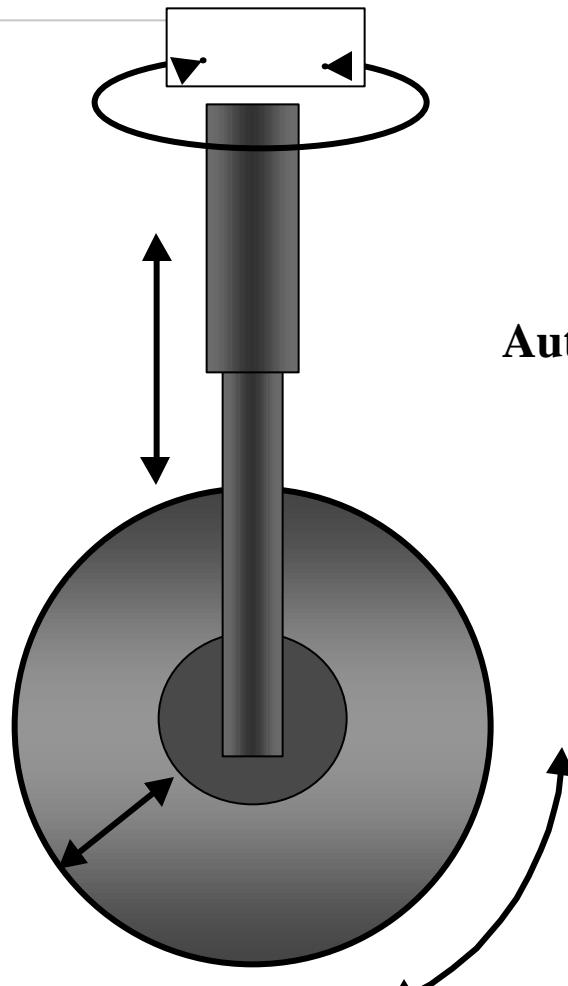
Vertical-offset stereo cameras provide range to horizontal shadows.



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Intelligent Wheel Module: Embedded Sensors, Controllers and Actuators



Sensors measure forces and response

- Wheel spin rate and drive torque
- Vertical strain, rate and position
- Twist strain, rate and position
- Tire pressure

Automatic controllers optimize mobility

- Minimize slip during acceleration, braking, steering and side slope traverse
- Minimize rolling resistance during on-road travel
- Minimize shock and vibration transmitted into the chassis

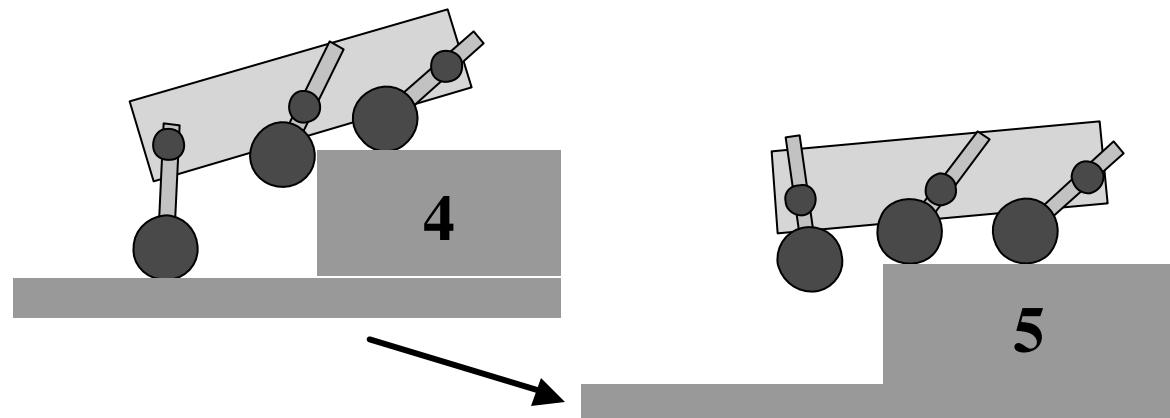
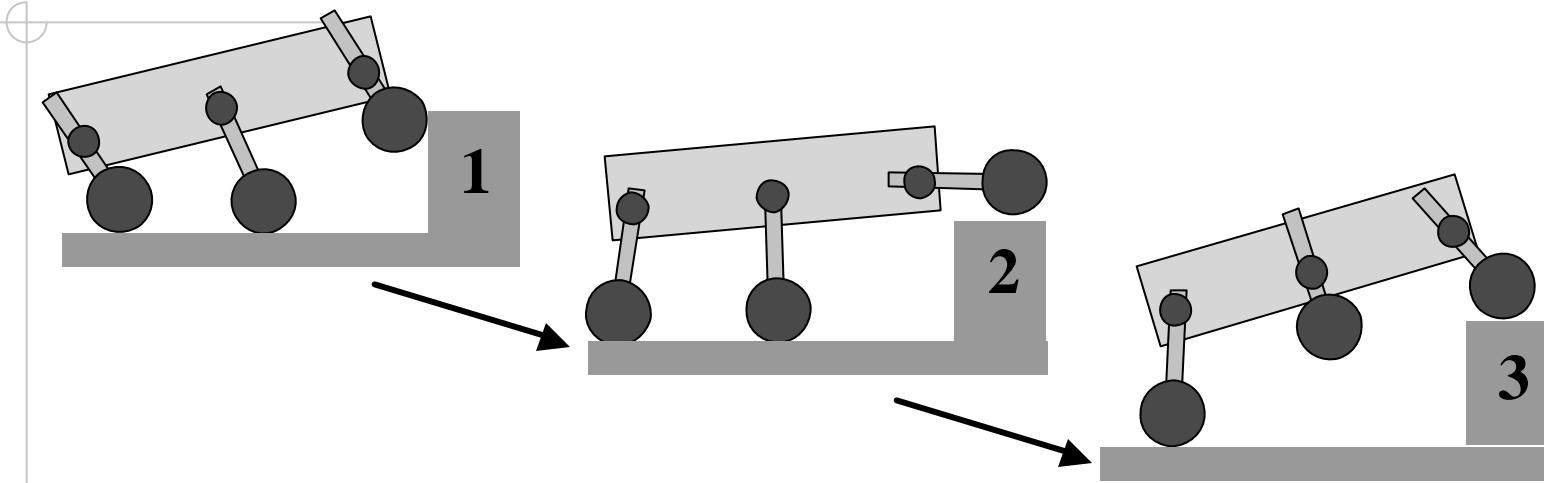
Actuators control 4 degrees of freedom

- In-hub electric drive
- Vertical displacement, damping and adjustable/variable spring stiffness
- Steering
- Tire pressure

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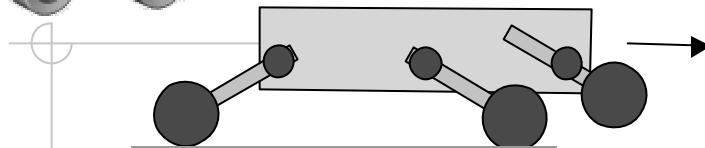
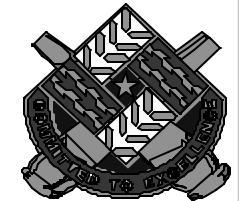
Walking/Climbing Gait for Vertical Obstacles (6-Wheel Drive and 2-DOF Active Suspension)



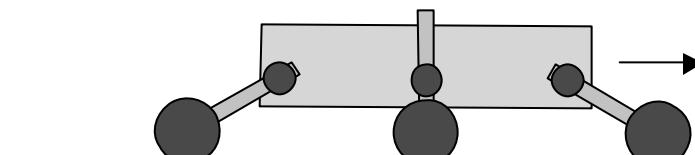
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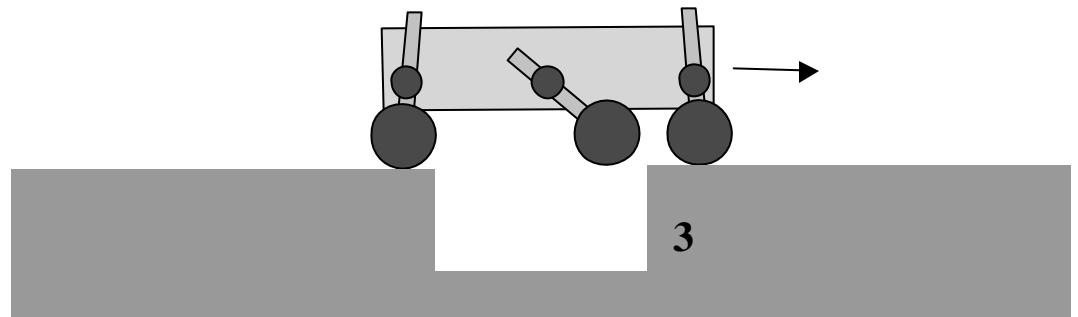
Crevasse Crossing with 2-DOF Active Suspension



1

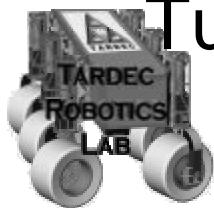


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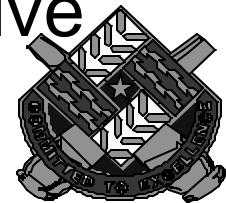
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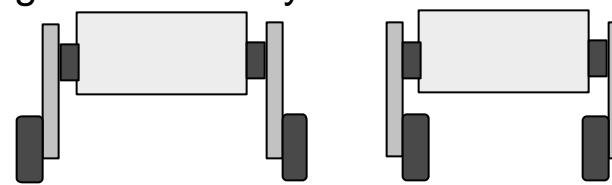
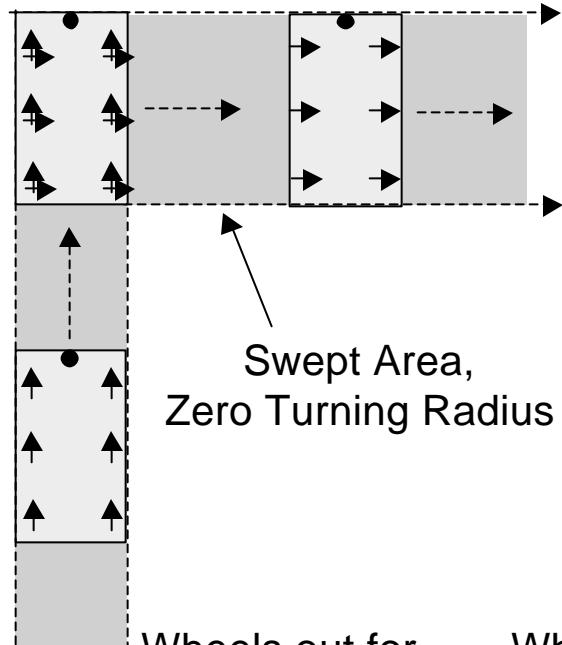


Turning Maneuvers w/ Omni-Directional Drive

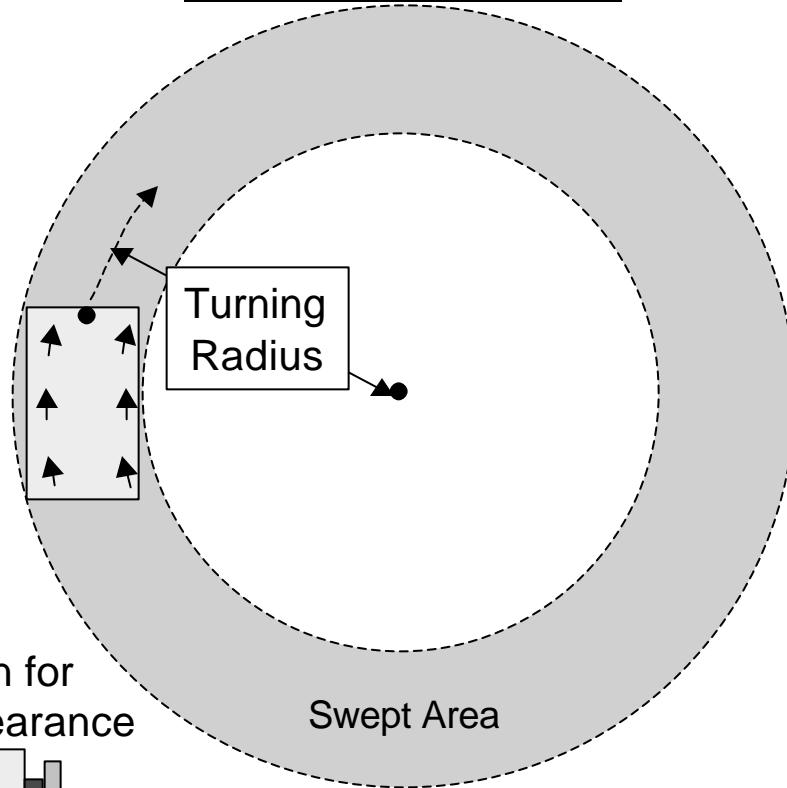
(Turning Radius vs. Swept Area Tradeoff)



Fixed Body Axis Steering



Ackerman Steering





FY01 and Beyond: The Modular Chassis



Chassis has three parts:

- Core unit consisting of the mechanical frame, power/distribution, and connection ports
- Vmetronics system, including multi-processors and wireless communication link to OCU
- System software

Connection Ports supply

- “Plug and Play” connectivity
- Power to/from peripherals
- Data communications
- Structural support for peripherals

Locomotion Peripherals are used to provide mobility capability

- “Snap and Lock” connections

- Modular system concept

- Deploy and a variety of mobility concepts, such as

- ODV smart wheel

- Hybrid track wheel

- “Legs”

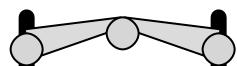
- Fixed wheels

- Tracks/skid steer

- Pontoons/propellers

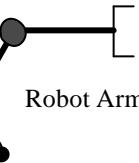
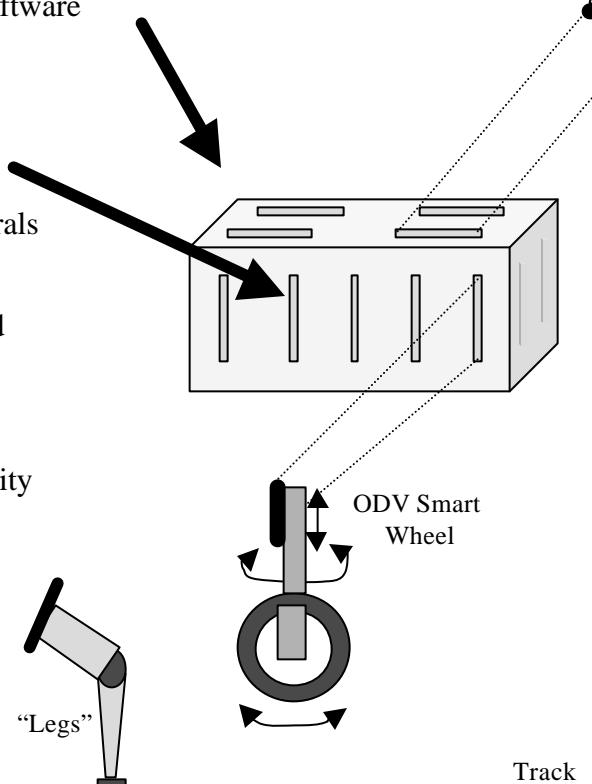
- Others

- Multi-vehicle coupling



Multi-vehicle coupler

Core Chassis



Mission Peripherals provide the vehicle with a reason to exist

- “Snap and Lock” connections
- Provides variety of functionality
- Manipulation concepts such as
 - Robot arms and end effectors
 - Forklift mechanism
 - Explosive ordinance handling
 - Welding fixtures and torches
 - Mission-specific “jigs”



Camera/
Sensor Pack

ODV Smart Wheel



Track Drive

“Legs”

Multi-vehicle coupler

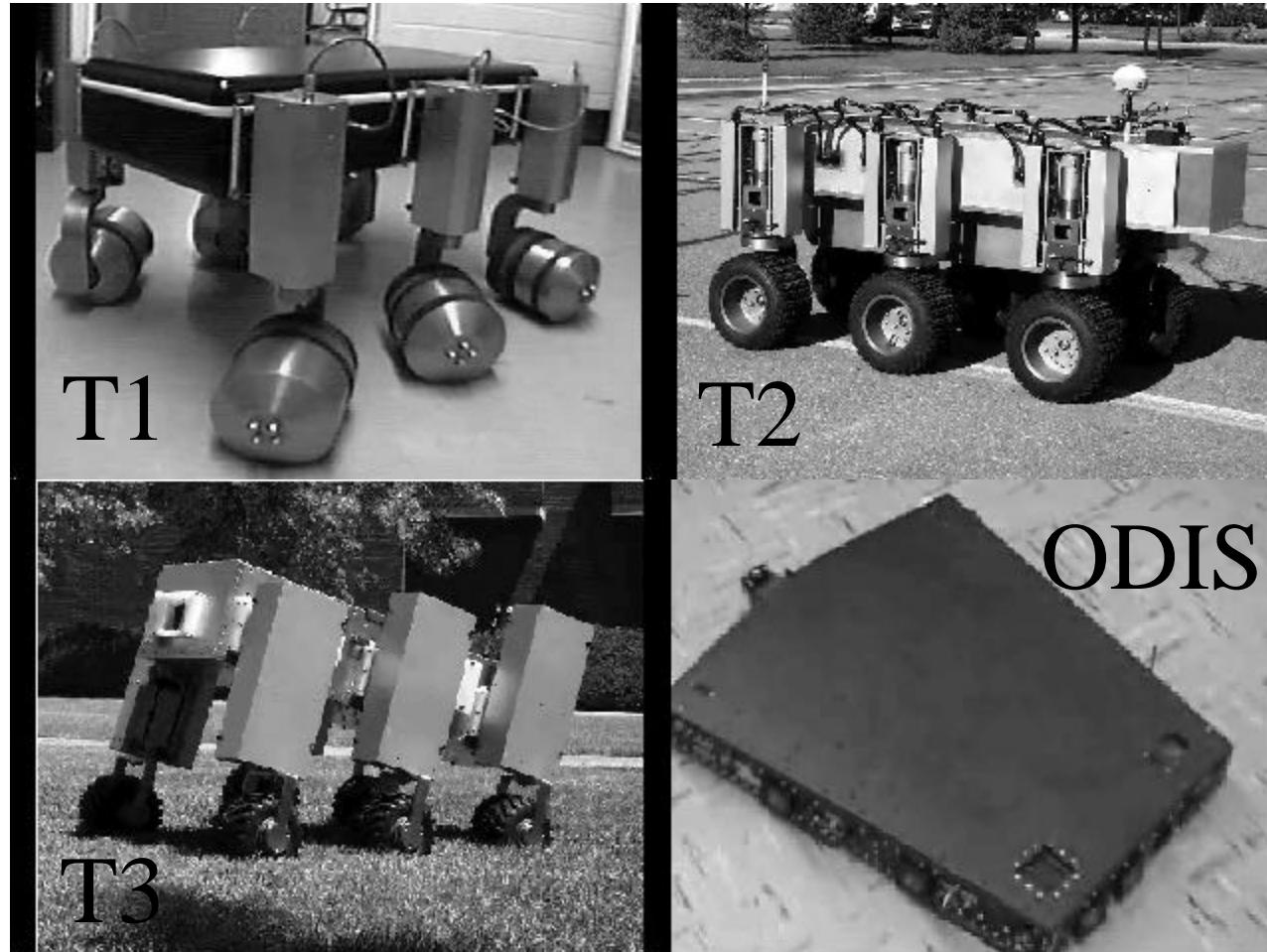
Core Chassis

Sensor Peripherals enhance the chassis

- “Snap and Lock” connections
- Sensor packs
- Batteries/generators
- High BW Communications
- Additional computing capability



T1, T2, T3, and ODIS



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